A COMPARISON OF HARDNESS AND ABRASION RESISTANCE OF TWO SEALANT MATERIALS AFTER POLYMERIZATION FROM DIFFERENT DISTANCES BY DIFFERENT LIGHT SOURCES

by

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INTRODUCTION

Healthcare in today's society has become an expected and necessary commodity for the general health of an individual. Many changes have taken place in healthcare in the past 100 years. Technology, education, science, management, and cost are only a few of the areas that have seen drastic changes. These changes are generally for the good of the patient and continue to evolve and change as healthcare progresses in this new century. As a component of modern day healthcare, dentistry has experienced many of these same changes.

There is a constant influx of new technology, techniques, ideas, and products being introduced and used in the dental healthcare field. All of this new science and technology is supposedly aimed at making dentistry better and more user friendly for both the patient and the practitioner. In looking at the big picture of dentistry, it is hoped that better dentistry equates to better overall health, longevity, and quality of life.

It is recognized that the constant barrage of new products, marketing claims, and technology leads to many questions among practitioners concerning validity, usefulness, appropriateness, and proper technique. How is a conscientious practitioner to approach the daunting question of which material, technique, or technology is the best, easiest, and most effective for their practice and their patients?

A dentist knows that sealants are good for their patients but may be unsure of which one to recommend, how to place it, which light to use for polymerization, what technique to employ to ensure proper placement, etc. A constant learning process is therefore imperative in order to make the best decisions and consistently achieve the best results.

How many of the new dental materials, techniques, and wonder drugs are really effective, as opposed to just marketing noise, is up for debate. This research aims to answer a few questions about a proven therapeutic and preventive dental procedure. Dental sealants have been in use for many years as a preventive measure. Their effectiveness is not the question of this study. This project hopes to answer some questions about the best method or technique for polymerizing sealants once they are placed on the teeth. Particularly, which lights may be most effective and which distance is optimal for complete curing of the material? It is hoped that insight will be obtained in this area by testing three different light sources, at three different distances, while polymerizing the chosen sealant materials. Specimens will be made by polymerizing the materials with the different lights from different distances. We will then try to analyze which variables are the most successful by testing the specimens for hardness and abrasion resistance. In resin composites, the physical properties are closely related to the degree of polymerization, and hardness measurement has been shown to be an effective way to evaluate this degree.[1,2] Abrasion resistance is one of the main indicators for proposed longevity of the sealant material after it is placed.[3,4]

REVIEW OF THE LITERATURE

There has been a generalized and dramatic reduction in the amount of untreated caries in the last 50 years. This trend is seen in all of the four major demographic indices of age, sex, race, and poverty level.[5,6] Although there is a decline across the board, it is a fact that there is still a large population of children with untreated dental caries. It is estimated that 25% of children have 75% to 80% of the decay.[7-9] The largest numbers of these children typically are minorities, are rural dwellers, have minimal exposure to fluoride, or come from poorer or less educated families.[8] Early childhood caries is among the most prevalent health problems of low-income infants and toddlers.[10] Even though children, in general, have experienced a decline in caries, this decline has not been equal to the extent of decline of caries in adults.[5,6] Five out of six 17 year olds have at least one decayed, missing, or filled surface (DMFS), with a mean of eight DMFS per 17 year old.[8] Yet it has been noted that recent surveys show as many as 60% of children under the age of 10 have a caries-free primary dentition. This same study suggests that 55% of 5 to 17 year olds have a caries-free permanent dentition.[7,9] Many factors have contributed to this decline, including better patient education, fluoridated water, better access to care, fluoridated toothpaste, and higher social standards in general for dental care.

In recent years, the use of dental pit and fissure sealants has come to represent a major shift from restorative to preventive care in children. The American Academy of Pediatric Dentistry's guidelines for preventive dental services recommends that sealants be placed on primary molars when indicated and on first and second permanent molars as soon as possible after eruption into the mouth.[11] Pit and fissure caries are the most common form of caries in 5 to 17 year olds and make up about 90% of the total caries experienced.[5-9,12] It is quite obvious that pit and fissure caries represent a substantial proportion of the caries experience in the primary and permanent dentition of children and adolescents.[12,13] It is now widely accepted that dental sealants are extremely efficacious as a preventive aid against pit and fissure caries.[14-18]

Advocacy of the use of pit and fissure sealants as a useful and important step in preventive dentistry is not a new idea. Many studies have shown the benefits of sealants and their importance as a component in the overall healthcare of children.[15,19-27] Sealant use has many advantages. For example, it has been demonstrated that if sealed in, bacteria tends to die out and early carious lesions do not progress.[15] Sealants have also been shown to be cost effective and, when placed correctly, have a high degree of retention.[12,14-16,21,23-25,28-30] When used to seal over other restorations, sealants actually improve the long-term stability and durability of those restorations.[31] The proper use of sealants in children has been shown to be a very effective and important practice in reducing and helping to prevent occlusal caries in individuals.[14,21,23,30,32,33] Unfortunately, sealant use is not yet universal or foolproof. In 1996 it was found that fewer than one in five U.S. children and adolescents, ages 5 to 17 years, had one or more sealed permanent teeth.[7] In fact, the use of sealants by the dental profession is still far short of expectations or the ideal.[15,23] Poor retention and excessive wear are frequently cited reasons limiting the use of this preventive technique.[3,4,24,25] Yet, these same studies have shown that *all* fissure sealants undergo a progressive wear process, which exposes previously covered areas of the occlusal surface.[3,4] Simonsen[24,25] measured 10-year and 15-year retention rates and found that in 15 years, the studies still showed a 27.6% complete retention and a 35.4% partial retention on permanent first molars. This shows that over 60% of sealants were still present, even if some were only partially retained. While these numbers are not perfect, the rate of carious or restored teeth was 31.3% in teeth that had been previously sealed compared to 82.8% in teeth that had not been sealed.[24,25] It can be conjectured that if the retention level could be increased, the decay level would be lower. Feigal[21] states that sealants are effective caries preventive agents to the extent that they remain bonded to teeth. Feigal goes on to say that careful analysis of studies to date reveals a measurable failure rate, between 5% and 10% per year, which must be addressed. Thus, while sealants are an effective tool in preventing decay, they require vigilant upkeep and monitoring in order to increase their probability of success and overall usefulness.[19]

There are numerous variables involved in the outcome of successful sealant placement.[3,34] Some of those variables include light source (intensity and type),[2,34-39] length of time of polymerization and distance from the material (varies for each source),[2,34,40] properties of material (filled, unfilled, light, or chemical cure),[39,41-43] and operator technique (bonded, etched, primed, or isolation),[14] etc.

LIGHT SOURCE

There have been numerous studies on curing light units and their effectiveness. Many of these studies focus on comparisons between types of lights, and many focus on the quality of the lights being used. Conventional halogen lights are the current gold standard against which all other lights are usually measured.[38,44-48] Generally halogen lights perform better than the challengers but require constant monitoring because they can diminish in light intensity over time.[36] The bulb power can decrease and many practitioners continue to use the light without even knowing that there is a problem.[49] Some studies have found that over 50% of the light curing units in dental offices are not effective at curing and need repair or replacement.[50-53] Yet, the performance of these lights is essential in achieving an adequate polymerization of resin materials. Inadequate curing has been associated with retention failure, weaker restorations, higher solubility, and pulpal responses to residual unpolymerized monomers.[54-57]

New lights on the market are advertised as having more intensity and requiring less time. These lights are marketed aggressively to practitioners as the newest money- and time-saving tool for their practice and the newest, best thing for their patients. Yet, many of these new lights are untried, untested, and unproven in real-life situations or even in quality scientific studies.[58] How can a practitioner know if these lights really work and if they can trust the manufacturers' claims? Light-emitting diode (LED) lights are the newest in the group and show great promise,[45,48,59,60] but they generally perform below or, at best, on par with halogen lights.[61] An increase in light intensity is known to produce greater surface hardness in composite resins.[62] Marais et al.[62] completed a study in an effort to determine the depth of cure established in composite resin specimens when polymerized with curing lights of differing intensities. One light produced 600 mW/cm^2 and the other produced 300 mW/cm^2. These lights then cured resin specimens of

1, 2, 3, 4, and 6 mm thicknesses. The samples were then tested using Vickers hardness immediately and then again one hour later. The researchers found that there was a significant decrease in hardness with each increase in the depth and that beyond 2 mm was the greatest difference in polymerization. Materials only reached optimal hardness after one hour. Marais et al. concluded that light curing resins should not be polymerized at a depth of greater than 2 mm and that beyond this thickness, an increased light intensity did not produce any significant increase in the Vickers hardness of the materials.[62] Because of this study and others like it, practitioners generally feel that 2 mm is the maximum thickness of resin that can be polymerized with any degree of confidence.[63,64] The thickness of the specimens in this study is based partly on this premise and will be explained in more detail later in this paper.

Leonard et al.[49] found that all light curing units are not the same. Leonard et al. tested three LED lights against a conventional halogen light and found that without exception, the LED lights performed more poorly than the halogen light at curing resin composite material. The LED lights required more polymerization time to cure the material sufficiently. Leonard et al. also found that the halogen light produced a significantly greater depth of cure, but both types of lights met the minimum requirement for the International Organization for Standardization depth of cure testing.

TIME AND DISTANCE

The distance of the light tip to the material being polymerized has been shown to have a direct effect on depth of cure and light intensity.[35,40,65-67] Pires et al.[36] found that light intensity diminishes as the curing tip is moved farther from the resin material. The researchers studied the effects of distance on microhardness and light intensity. Specimens were cured at various distances (from 0 mm to 12 mm) and then tested with Knoop hardness to determine polymerization levels. The Pires et al. findings showed that hardness of top and bottom surfaces increased with greater light intensity, which was correlated with the shorter distances. The depth of cure was reduced as the distance from the light tip was increased. The authors' conclusion was that the manufacturers' recommended curing times should be extended whenever light intensity is compromised by distance or any other factor. Sobrinho et al.[34] found that greater distance between the curing tip and material created lower Knoop hardness values but was dependent upon the material being tested. Sakaguchi et al.[37] and Sakaguchi[68] state that curing light intensity and polymerization diminish rapidly for any distance greater than 2 mm between the tip of the light guide and the material surface. Tanoue et al.[69-71] consistently found that depth of cure of resin materials is directly affected by length of time of polymerization. Longer exposure time increased the depth of cure in all materials and combinations studied by Tanoue et al.

PROPERTIES OF MATERIAL

One study looked at six different resin materials that were cured with 14 different light sources. These lights were made up of seven different halogen lights, two Argon lasers, and five plasma-arc lights. The researchers then tested the materials for shrinkage, heat generation, strain, and physical changes on the teeth and resins during strain testing. The results of the study showed that the effects associated with the lights were not statistically significant, but the restorative materials' formulation was highly significant. The purpose of this study was to assess the lights for negative effects that they may be responsible for, but it showed that the polymerization problems stemmed from the components in the resins themselves. The samples were all cured according to manufacturer's instructions to minimize the operator error with polymerization technique.[43] Had the technique been altered during polymerization, the authors may have found statistically significant issues with the lights being tested. Other studies have specifically tested the materials for durability, strength, longevity, and overall quality based on their formulations and chemical component makeup. Ulvestad[72] equated the durability of a sealant material to its wear resistance. Ulvestad stated that one of the methods to evaluate the resistance of a material to wear is to subject it to a hardness test. The harder the material, the more likely it is to resist wear and, therefore, be more durable and successful. Ulvestad found that sealants with inorganic filler particles had a considerably higher surface hardness than those materials that were unfilled.[72] Another study showed that the abrasion resistance of unfilled resins is much poorer than that of filled resins.[73] It has also been shown that filler size has a direct effect on depth of cure.[34]

The present study uses a filled and unfilled resin sealant to determine if these findings hold up when the light curing units are varied and the polymerization techniques are altered.

OPERATOR TECHNIQUE

The practitioner can do many things to improve the quality of his/her sealants.[66] Use of a rubber dam for isolation is one of the easiest and best steps to take for better results. Kersten et al.[14] state that simple changes or variations in operator technique can improve the quality of the sealant material's ability to do its job – namely to seal the tooth. Suggestions include ultrasonic treatment during etching or drying with acetone-based products prior to placement of the sealant. Borsatto et al.[30] assessed microleakage under pit and fissure sealants after the enamel had been etched in different ways. Borsatto et al. found that acid etching was the best method and produced the least amount of microleakage. Other studies have found that bonded sealants have less microleakage and greater longevity than sealants that are placed without bonding agent. There are many ways to increase one's chances for success with sealant placement, and this study hopes to aid the practitioner in achieving greater success with sealant longevity.

The overall objective of the proposed research is to determine if there is any significant clinical difference in the polymerization and integrity of sealant material if the operator varies the curing technique (distance of curing light from sealant material) or uses different technologies (halogen versus LED). A recent study by Kim et al.[52] tested microhardness and wear of sealant material that was polymerized with different light sources at different times of polymerization. The study then compared the wear and hardness of the specimens with their curing times and light sources to find the levels where they were similar.[52] This study will measure similar properties of sealant material but will focus on different variables of the polymerization process – namely the distance between the light source and the sealant.

Sealants are only effective if they are placed in a manner that allows them to effectively bond to the tooth and to have the sealant material remain for as long as possible.[3,12,14,19,38] A sealant's ability to bond to a tooth is reduced when it is not cured completely.[12,34,36,38,64] An incomplete polymerization will decrease the strength of the sealant material, cause wear and early loss, and thereby limit the effectiveness of this preventative modality.[14,28,39,41,52,64,74] Any method or technique that will help practitioners to ensure sealant strength and longevity would be beneficial, both to the practitioner in terms of successful treatment and revenue, and to the patient for cost and long-term oral health.

METHODS AND MATERIALS

Two sealant materials were used in this laboratory study: Ultraseal XT (Ultradent Products, Inc., South Jordan, UT) and Delton (Dentsply International, Woodbridge, Ontario, Canada). Delton is a sealant material that has been in use for many years and is often used as the control in other studies concerning sealant materials.[29,75] Three different light sources were used to polymerize the sealant materials: a traditional halogen light source QHL75 (Dentsply International, Woodbridge, Ontario, Canada) and two LED lights, which included the Ultralume LED (Ultradent Products, Inc.) and the 3M Freelight LED (3M Corp., St. Paul, MN).

The samples were prepared as follows. A prefabricated cylindrical Teflon (E. I. du Pont de Nemours and Company, Wilmington, DE) ring was used to allow for placement, curing, and easy retrieval of the sealant material specimens, which were then tested for Knoop hardness and abrasion resistance. An earlier study used similar rings to create sealant material samples of 1 mm thickness and 7 mm diameter.[76] The researchers went on to test the sample for porosity and showed that specimens of this size are viable for testing purposes. Many other studies have shown that the use of specimens of similar size and shape is appropriate and effective for testing of resin materials.[2,34,36,49,52,64]

The rings enabled the creation of uniform specimens of identical dimensions and thicknesses of 2 mm by 6 mm. The 2 mm thickness of the sealant material specimens in the present study is partly based on the findings of earlier studies previously mentioned, but it is also based on the reality that 2 mm of sealant depth is clinically relevant.

The variation of virgin, unprepped teeth in cuspal height, depth of fissures and grooves, anatomical structures, and general variation all lead to the possibility of material depths that could reach or even exceed 2 mm in normal sealant placement. The days of cavity preparation following the adage of "extension for prevention" are gone. Today, most practitioners follow conservative treatment guidelines and strive to preserve as much of the tooth structure as possible. Thus, conservative preparations are changing the way that caries is being diagnosed, treated, and prevented.

When taken into consideration, the use of sealants on teeth that have been conservatively prepared with a bur such as in a "round bur" or "fissurotomy" preparation, the reality of a 2 mm depth of material becomes even more evident. Many sealants are also touted as flowable resins, to be used interchangeably as a sealant or a flowable composite material as the practitioner sees fit. This means that some sealant materials may be used in even deeper cavity preparations as liners, bases, or other adjuncts to larger restorations.

All of these factors contribute to the idea that a thin layer of sealant material is not the only thickness that should be considered in the modern dental age when studying the level of polymerization of sealants. The international standard[18] for depth of cure for sealant material using any light source is 1.5 mm, and the American standard[17] for depth of cure for sealant material using any light source is only 0.75 mm. These depths are adequate when viewing sealant material as a an ideal, thin layer on the surface of the tooth, but these depths lack sufficiency when taking into consideration the reality of how sealant materials may be used in today's dental environment.

Each specimen was polymerized from one of three different distances of 0.5 mm, 2 mm, and 10 mm. The rings were placed on a glass slide and the material was expressed into the center, being careful to reduce the amount of bubbles present. Ultraseal XT was delivered in a syringe and was easily "injected" into the mold with few inclusions of bubbles, whereas Delton was delivered in a carpule and consistently had problems with air bubbles becoming entrapped in the specimens.

After placement in the mold, the samples were covered with a thin glass cover slip in order to obtain a smooth surface for Knoop hardness testing. Leonard et al.[49] showed that a glass cover slide was better than a mylar strip because glass demonstrated a minimal power loss through the glass of less than 5%, as compared to 10% with a mylar strip.

Each curing distance was used for one sample group, which consisted of four individual specimens for hardness testing and six individual specimens for abrasion testing. (Separate specimens were prepared for each, testing the modalities of hardness and abrasion.) The distance was gauged from the tip of the light source to the material and was maintained by attaching a flexible metric ruler to one side of the light source tip for the 2 mm and 10 mm groups. The 0.5 mm group, or "contact" group, was measured simply by using two glass cover slips on top of the material, the thickness of which is 0.5 mm. The LED and halogen light sources were used to cure each sample group at each distance, creating 18 different sample groups of polymerized sealant material (i.e., three distances and two materials for a total of six sample groups for each of the three light source.) Each specimen was light cured for the time recommended by the manufacturer, which was 20 seconds. The different sample groups were then tested for hardness and abrasion resistance to determine if significant differences existed in the curing techniques.

FACILITIES AND EQUIPMENT

This study was conducted in the dental materials research laboratory at the Indiana University School of Dentistry. All testing equipment and materials were provided or made available from this testing laboratory. The equipment that was used was a Knoop hardness-testing machine and a toothbrush abrasion-testing machine.

The Knoop hardness-testing machine tested the sample groups at 10gf from each sealant material cured at each of the three distances from each curing light source. There were four hardness measurements per specimen, per surface (top and bottom), and an average value was then obtained for each surface. This created 18 sample groups that were tested for hardness. Each sample group contained four individual specimens; thus, 72 individual specimens were prepared for hardness testing.

The toothbrush abrasion machine tested new sample groups from the same curing light sources, sealant materials, and curing distances. Hardness testing was completed first and, in so doing, it was found that some of the sample groups did not cure sufficiently to be tested. The following sample groups were left out of the abrasion resistance testing because of the lack of sufficient polymerization: Delton at 10mm with all three lights, Delton at all distances with the Freelight, Ultraseal at 10mm with the Freelight. This removes six of the sample groups from possible testing. Thus, only

12 new sample groups were created for abrasion resistance testing. Each sample group had six individual specimens, which created 72 individual specimens that were tested in the toothbrush abrasion machine. These specimens were prepared the same way but were affixed by bonding to a standard glass slide after curing. The prepared slides were weighed for initial mass of the specimen and then placed in the abrasion machine and run through a cycle with the toothbrushes. Generally, one cycle of 20,000 brush strokes with a load of 200 g simulates one year of brushing. A solution of Crest Kid's Sparkle Toothpaste (Proctor and Gamble, Cincinnati, OH), diluted 1:1 with distilled water, was added to create a paste and to function as an abrasive material. After the abrasion cycle the specimens were rinsed and weighed again to determine the loss of material mass as a result of the abrasion.

A two way ANOVA was run to analyze all the data from the abrasion resistance testing. Additionally, for the Delton abrasion specimens, four separate student t-tests were conducted because there was a very significant interaction term of the factors involved. One factor was the two curing units, the other factor was the two curing distances. Also, for the Ultraseal abrasion specimens, a Student Neuman Keuls test was conducted to determine significant differences between light sources.

A two way ANOVA test was similarly conducted to analyze the data from the hardness testing.

RESULTS

Tables I, II, and III are complete summary statistics for all the samples tested representing the top surfaces, ratio of bottom/top surfaces, and bottom surfaces, respectively.

Tables IV, V, VI, and VII present the analysis of the comparisons of the data from the samples tested. Table IV shows results of comparisons of different curing lights used on each material at the same distance, while Table V show results of comparisons of different distances on each material using the same light. Table VI and Table VII present the data from the same comparisons for the bottom surfaces.

These tables show the p-values for the data comparisons. According to the statistical analysis, p-values greater than 0.05 represent a statistically significant difference in the comparisons of the gathered data.

TOP SURFACE HARDNESS

Light Source

The halogen light source consistently produced the "hardest" specimens. There was a consistent trend in mean hardness for curing units at each distance. For each type of sealant material, halogen has a greater mean hardness than Ultralume, which has a greater mean hardness than 3M LED.

This holds true for all treatment combinations, with the exception of one. This is the case of Delton sealant, cured at a distance of 2.0 mm. Here, Ultralume has greater mean hardness than halogen, which, in turn, has greater mean hardness than 3M LED.

Distance

There is an interaction between the sealant material, the curing source, and the distance, as all three curing units show different mean trends for distances for the different sealant materials. Expectations were that the closer distance would yield the best results, but the 0.5 mm distance was the worst distance in all but one sample group. The best distance was 2 mm, and two sample groups even scored best at 10 mm. This trend did not hold true for any other tests other than for top surface hardness. For example, mean hardness is greatest when cured at 2.0 mm for 3M LED for either sealant; however, for Delton sealants cured with 3M LED, curing sealants at 10.0 mm leads to greater mean hardness than curing sealants at 0.5 mm; while for Ultraseal sealants cured with the 3M LED, curing sealants at 0.5 mm leads to greater mean hardness than curing them at 10.0 mm. For halogen, mean hardness is greatest when cured at 10.0 mm for Delton sealants; while for Ultraseal sealants, mean hardness is greatest when cured at 2.0 mm. For Ultralume LED, mean hardness is greatest when cured at 2.0 mm for Delton sealants; while for Ultraseal, mean hardness is greatest when cured at 10.0 mm.

Examining the table of model-based comparisons for the effect of curing source reveals the following results for the top surfaces. For both sealant types, when cured at 0.5 mm or at 10.0 mm, halogen has significantly greater least square mean hardness than does 3M LED. When cured at 2.0 mm for Ultraseal, halogen has significantly greater least square mean hardness than 3M LED. When Ultraseal was cured at 0.5 mm or at 10.0 mm, Ultralume has significantly greater least square mean hardness than 3M LED. The comparison of Ultralume to 3M LED at 2.0 mm was marginally nonsignificant. For

Ultraseal cured at a distance of 2.0 mm, halogen has significantly greater least square mean hardness than Ultralume.

Examining the effect of distance, the table of model-based comparisons reveals the following for the top surfaces. For Delton cured with 3M LED or with Ultralume, least square mean estimates of hardness were significantly greater at 2.0 mm than at 0.5 mm. Also for Delton and 3M LED curing source, least square mean hardness estimates were significantly greater when cured at 2.0 mm than at 10.0 mm. For Ultraseal cured with halogen units, least square mean hardness was significantly greater when cured at 2.0 mm than when cured at 0.5 mm.

BOTTOM SURFACE HARDNESS

Light Source

We see a consistent trend in mean hardness for curing units at each distance. The halogen light source was first in every sample group as far as bottom hardness was concerned. For both types of sealant material, halogen has a greater mean hardness than Ultralume, which has a greater mean hardness than 3M LED. These results would suggest that the halogen light source demonstrated the best ability to cure all the way through the specimen. The 3M LED was last in each test and, at further distances, did not polymerize the material thoroughly enough for the bottom surface to be tested.

<u>Distance</u>

The results in regard to distance were more inline with the expected results. Generally, the further away the light source, the softer the material was expected to be. The worst distance each time was 10 mm, but 2 mm and 0.5 mm had equal billing as number one, depending upon the light and the material. For most, the differences were not significant, and when looking at trends of hardness means as related to varying distances, there was not a consistent pattern across the two sealant types and the different curing units. Ultralume shows greater mean hardness when cured at a distance of 2.0 mm than when cured at a distance of 0.5 mm. Ultralume also shows greater mean hardness when cured at 0.5 mm than when cured at 10.0 mm. This is also true for halogen with Ultraseal; however, halogen with Delton has greater mean hardness when cured at 0.5 mm than when cured at 2.0 mm. For Ultraseal, 3M LED has greater mean hardness when cured at 0.5 mm than when cured at 2.0 mm, which has greater mean hardness than when cured at 10.0 mm.

Examining the table of model-based comparisons for the effect of curing source reveals the following results for bottom surfaces: For both sealant materials cured at 0.5 mm, halogen has significantly greater least square mean hardness than 3M LED. For Ultraseal cured at 0.5 mm, halogen has significantly greater least square mean hardness than Ultralume, and Ultralume has significantly greater least square mean hardness than 3M LED. For Ultraseal cured at 2.0 mm and also at 10.0 mm, both halogen and Ultralume each have significantly greater mean hardness than 3M LED. For Ultraseal sealants cured at 10.0 mm, halogen has significantly greater least square mean hardness than Ultralume.

In analyzing the effect of distance, the table of model-based comparisons reveals the following for bottom surfaces. Least square mean estimates of hardness for Ultraseal cured with 3M LED are significantly greater when cured at 0.5 mm than when cured at 2.0 mm or 10.0 mm. Also for 3M LED and for Ultraseal, least square mean hardness estimates are greater when cured at 2 mm than at 10 mm. For both sealant materials cured by the halogen light, least square mean hardness estimates at 0.5 mm are greater than at 10 mm. Also for the halogen light and for Ultraseal, least square mean hardness estimates are greater when cured at 2 mm than at 10 mm. For Ultralume light with Ultraseal, least square mean hardness estimates are significantly greater when cured at 0.5 mm or at 2.0 mm than when cured at 10.0 mm.

RATIO OF BOTTOM TO TOP HARDNESS

Light Source

Again, the halogen light scored best in its ability to polymerize the specimen. This ratio is a measure of the specimen's top surface hardness in comparison to its bottom surface hardness. There is a consistent trend in mean hardness ratio for curing units at each distance. For each type of sealant material, halogen has a greater mean hardness ratio than Ultralume, which, in turn, has a greater mean hardness ratio than 3M LED. This holds true for all treatment combinations, except one – namely, Ultraseal cured at a distance of 2.0 mm. In that instance, Ultralume has greater mean hardness ratio than halogen, which has greater mean hardness than 3M LED. The data are relevant by giving an indication of depth of cure ability, penetration power, and relative intensity of the lights.

Distance

The distance of 0.5 mm gave the best ratio values in all groups except one – 10 mm was last in every test. For either sealant substance cured by any of the curing units, mean hardness was greatest when cured at 0.5 mm, followed by curing at 2.0 mm, with curing at 10.0 mm having the smallest mean hardness. This held true for all curing sources and sealant material combinations except for Ultralume with Ultraseal. These results indicate that in order to get a solid cure all the way through, especially in a thicker restoration or material, the operator's light needs to be as close to the material as possible.

When looking at the table of summary statistics for ratio, the mean of each ratio shows that neither of the materials has good results in any group. A mean of 0.8 (or 80%) would indicate an effective cure,[49,79-81] and not one combination of light, distance, or material was able to pass that number. This indicates that sealant material is not a good material to use for any restorative purposes that would necessitate any significant depth of cure.

ABRASION RESISTANCE

Table VIII presents the summary statistics for the toothbrush abrasion testing. Data from both materials are presented. Delton samples from 10mm (any light source) and Freelight (any distance) were not run due to lack of hardness in the specimens. Also, Ultradent samples from 10mm with the Freelight were not run due to lack of hardness in the specimens. Statistically significant comparisons are noted on the table.

Light Source

For all specimens tested, the Halogen light was best at creating a more thoroughly polymerized sample, as tested by the abrasion resistance. The Ultralume and the halogen lights were only significantly different in one area, and the two light sources were fairly even in each category. Both lights were significantly different than the Freelight in all categories. The three lights could only be tested against each other using with the Ultraseal sealant. The Freelight was significantly different from the others two light sources at both 0.5mm and 2mm. The 10mm distance could not be used due to poor polymerization. For Ultraseal, the halogen and the Ultralume had no significant differences between them.

The Freelight samples for Delton sealant were unusable for testing due to poor polymerization. One can surmise then, that the differences for Delton samples would also be significantly different between the Freelight compared to the other two light sources. With the Delton samples, a significant difference was found between the Ultralume and halogen light sources at 2mm., but not at the 0.5mm distance.

Distance

There were no significant differences in any of the materials with regard to distances tested. But, the 10mm. distance was not tested at all for Delton and was not run for the Freelight on the Ultraseal samples. Therefore, the assumption would be that at the greater distance of polymerization, there would indeed be a significant difference. Yet, for each light, the distances tested did affect the abrasion resistance of the sample tested. For the Ultraseal samples, the halogen light was nearly equal at 0.5mm and 10mm., but was better at 2mm. For the same samples, the Ultralume and the Freelight had a linear progression as the distances increased.

Similar results were found in the Delton samples from the halogen and Ultralume light sources. The halogen light produced better results at 2mm. than at 0.5mm while the Ultralume light produced the opposite results. This change results in the one significant difference between the two at the 2mm distance. It seems the halogen light is able to cure the samples best at 2mm. while the LED light always produced less favorable results the farther away they were from the sample. Either way, the Delton sealant material does not appear to be a good combination with the Freelight and based on this study, the two should not be used together. Conversely, the most abrasive resistant sample was created by the pairing of the halogen light source and the Delton sealant material at 2mm distance. Again, this shows that the materials and methods used by the practitioner can create a large variation of successful and unsuccessful outcomes. It is imperative that each practitioner be aware of the properties, research, directions, and recommendations for the products they use.

FIGURES AND TABLES

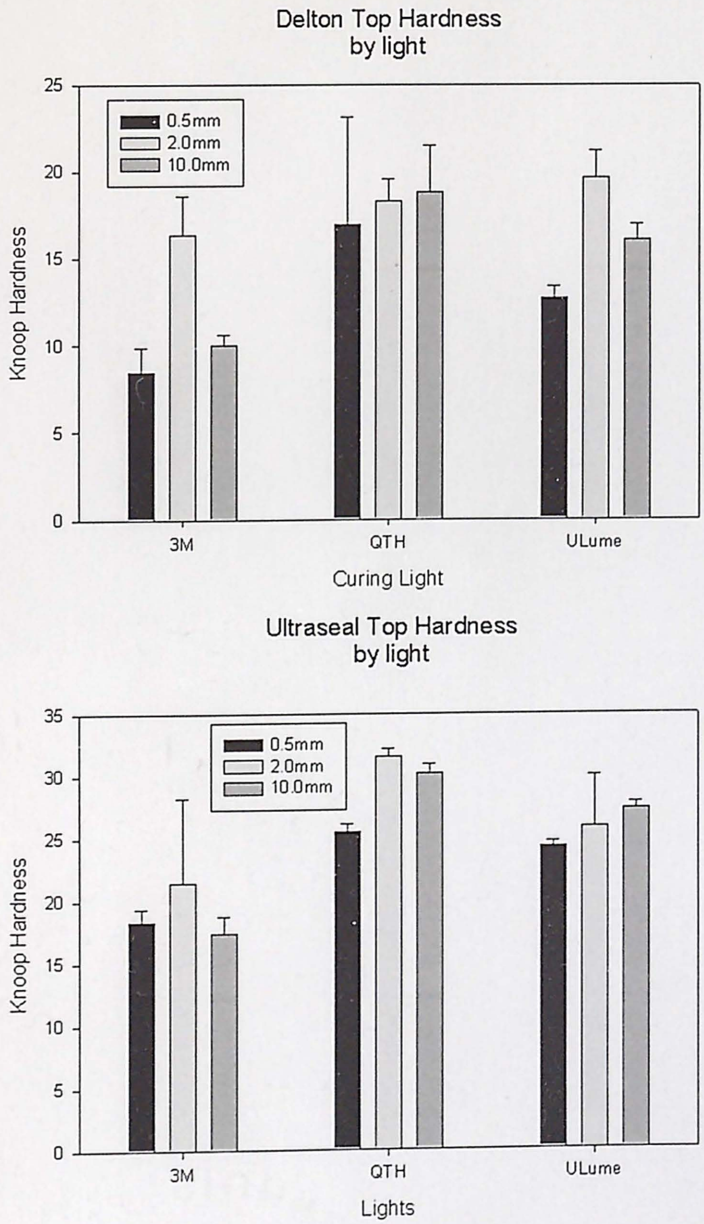
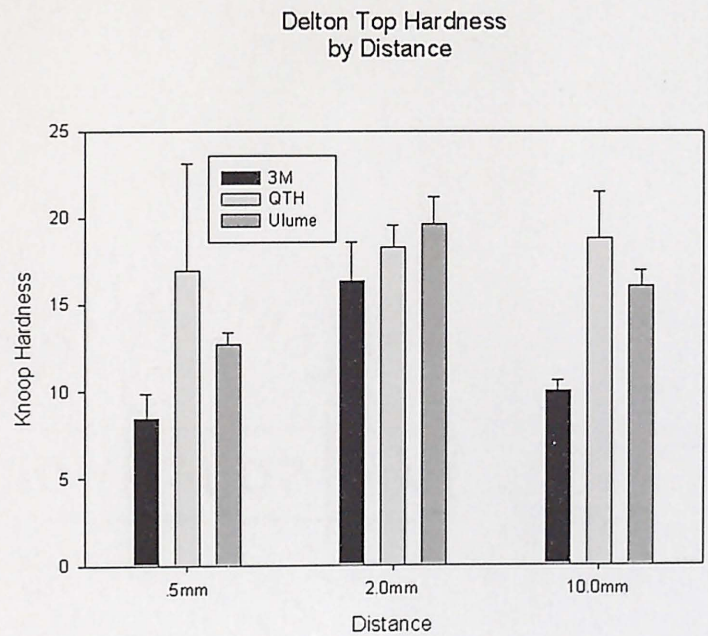


FIGURE 1 Top surface hardness with regard to light source.



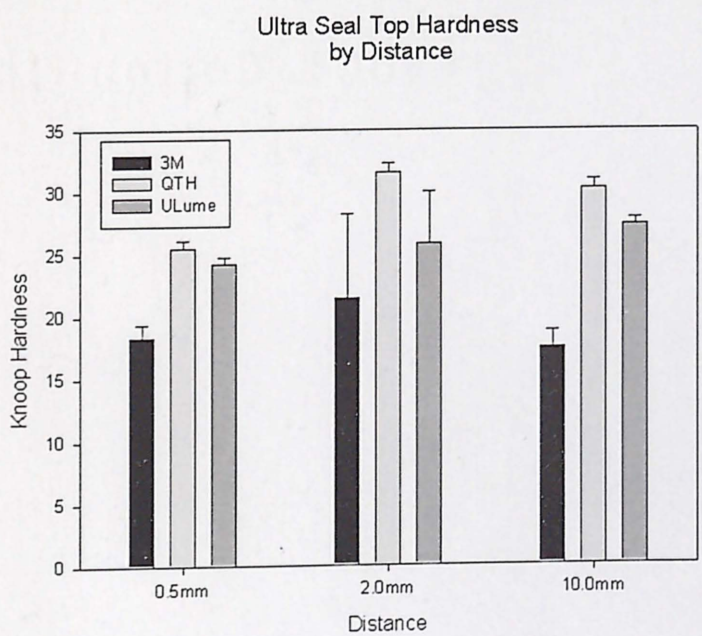


FIGURE 2 Top surface hardness with regard to distance.

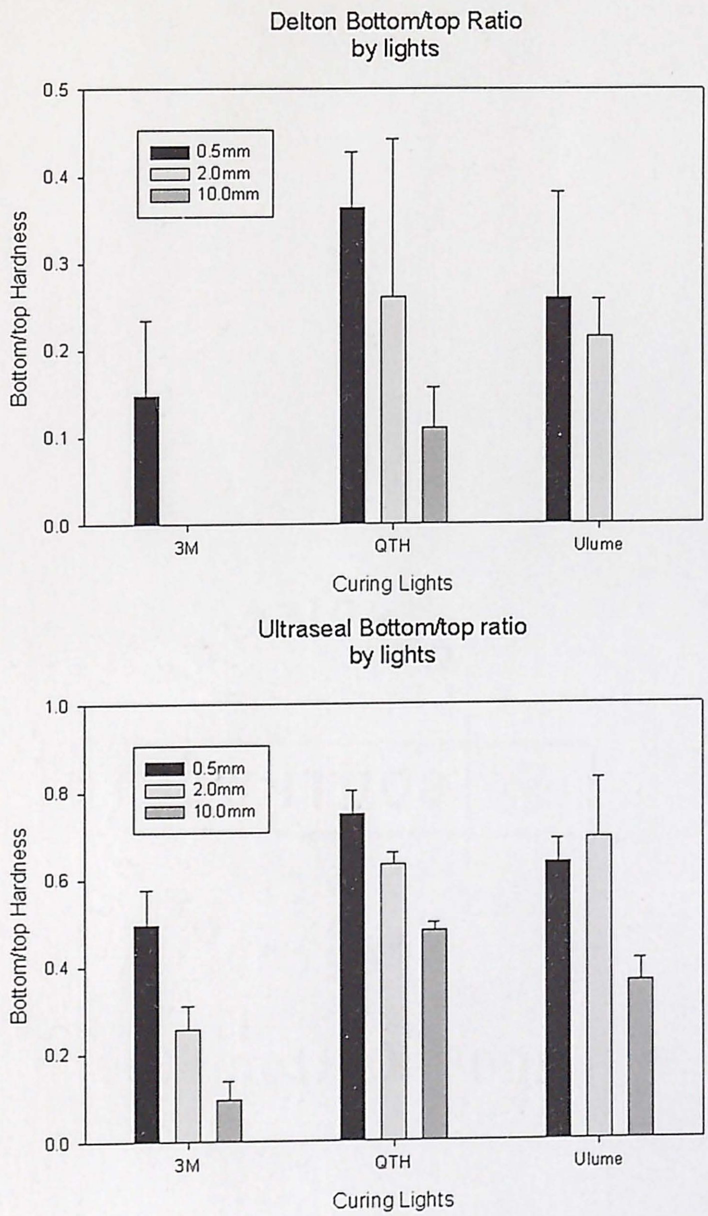


FIGURE 3 Ratio of bottom to top hardness with regard to light source.

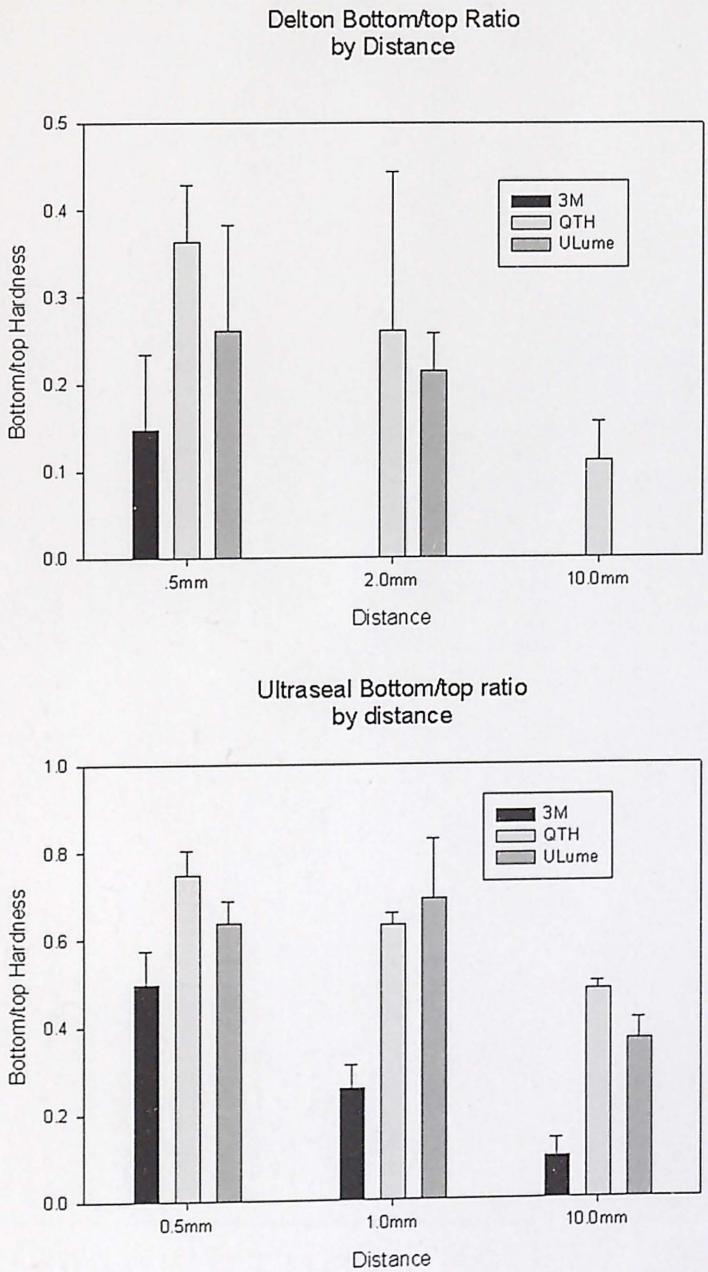
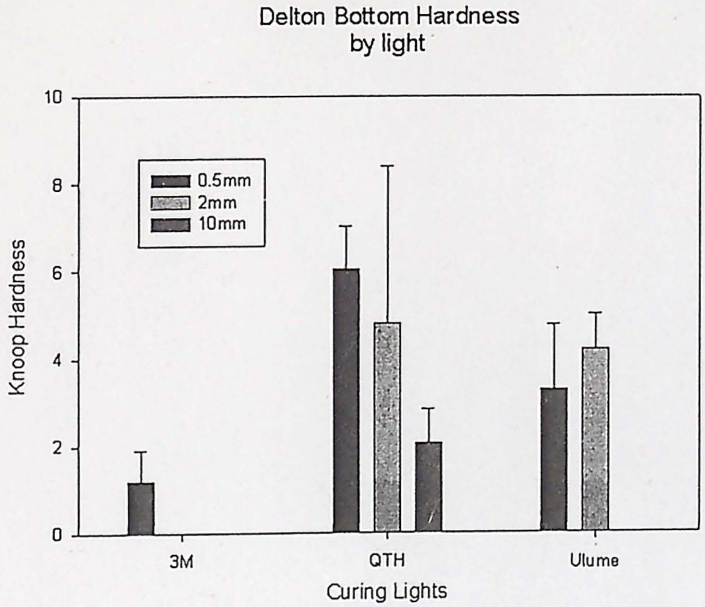


FIGURE 4 Ratio of bottom to top hardness with regard to distance.



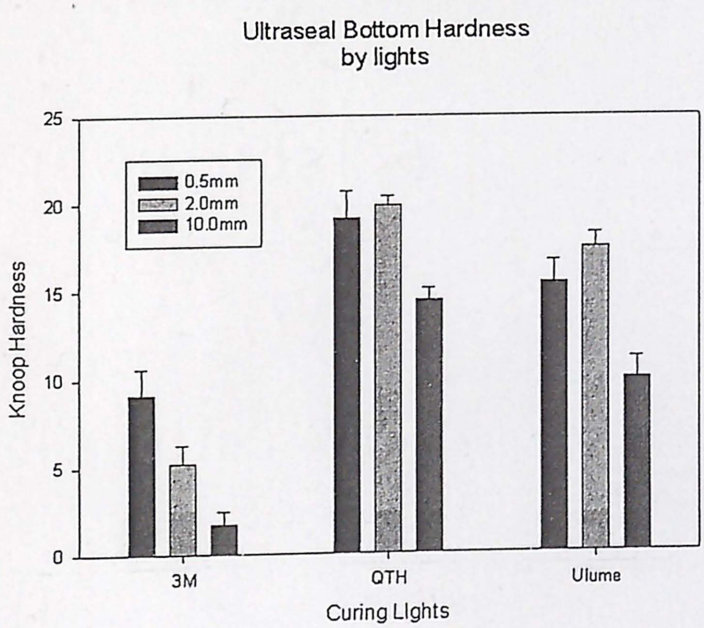
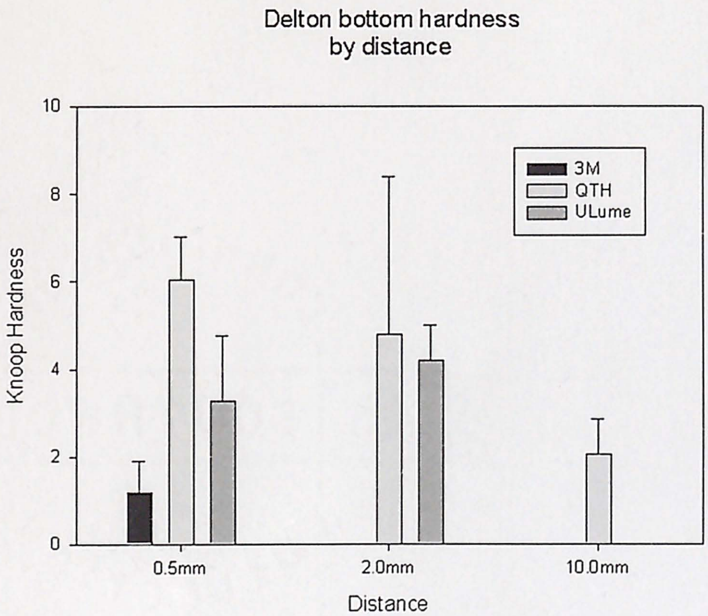


FIGURE 5 Bottom surface hardness with regard to light source.



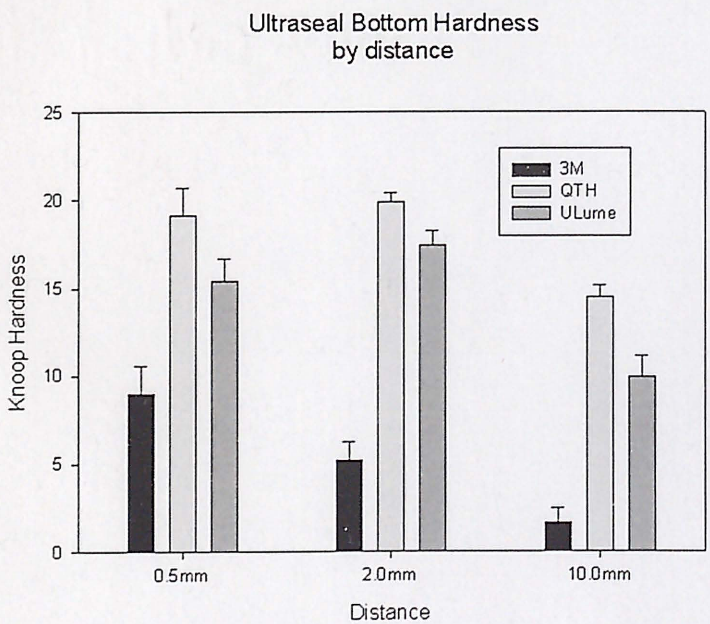
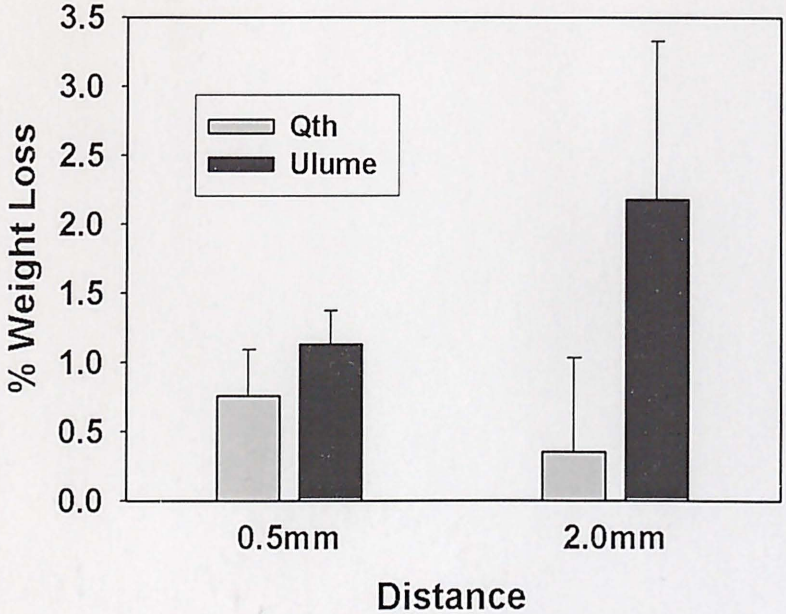


FIGURE 6 Bottom surface hardness with regard to distance.

Delton Toothbrush Abrasion by distance



Ultraseal Toothbrush Abrasion by distance

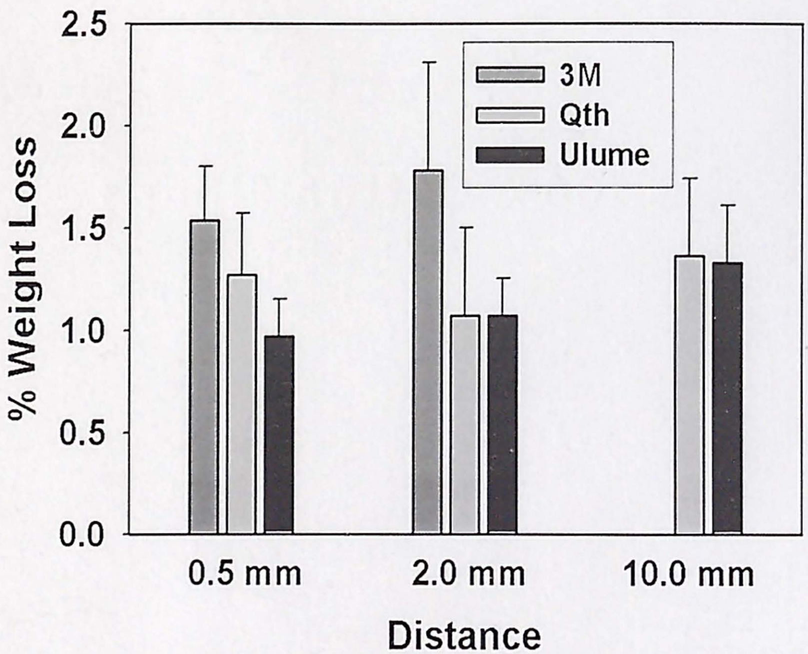
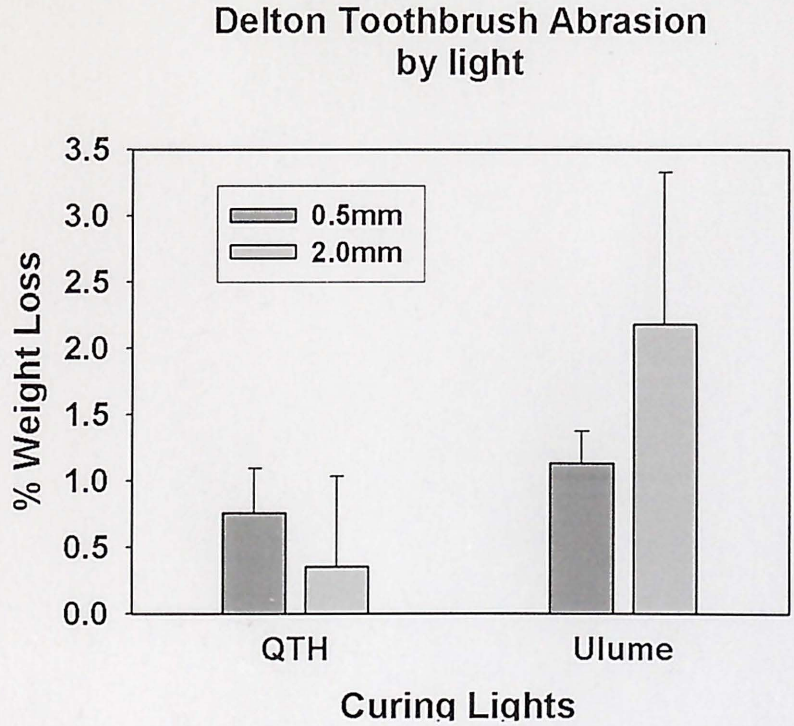


FIGURE 7 Toothbrush abrasion with regard to distance



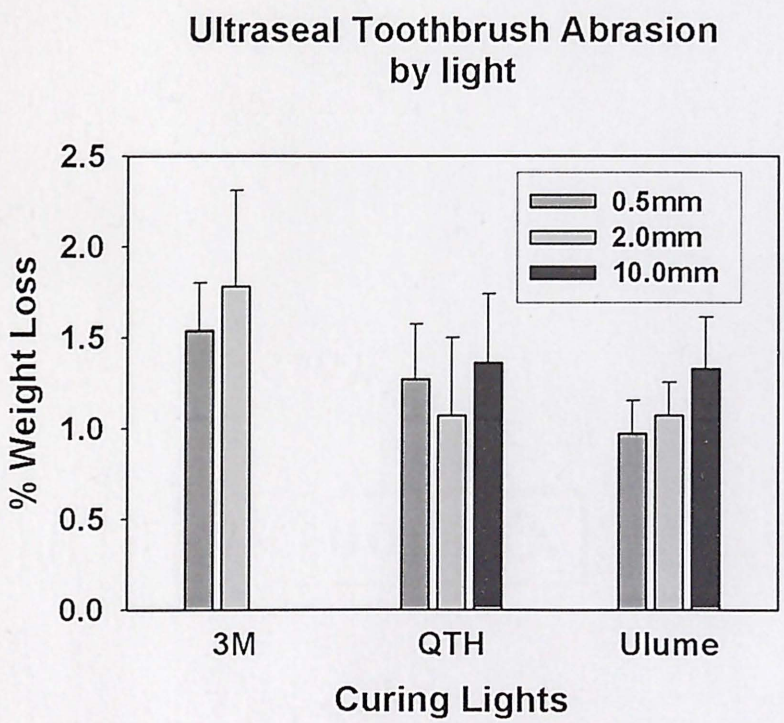


FIGURE 8 Toothbrush abrasion with regard to light source

TABLE I
Summary statistics for top surface hardness

Material	Distance	Curing unit	Mea n	Stddev	Stderr	Min	Max
DELTON	0.5	3M LED	8.450	1.380	0.690	6.6	9.6
		Halogen	16.950	3.167	1.584	12.6	20.2
		U LUME	12.700	0.648	0.324	12.1	13.6
	2.0	3M LED	16.350	2.249	1.124	14.7	19.6
		Halogen	18.250	1.328	0.664	16.7	19.5
		U LUME	19.650	1.544	0.772	17.8	21.2
	10.0	3M LED	9.975	0.613	0.307	9.2	10.6
		Halogen	18.775	2.659	1.329	15.0	21.1
		U LUME	16.050	0.911	0.456	15.2	17.3
USXT	0.5	3M LED	18.225	1.078	0.539	16.9	19.2
		Halogen	25.525	0.640	0.320	25.0	26.3
		U LUME	24.175	0.512	0.256	23.6	24.7
	2.0	3M LED	21.350	6.844	3.422	11.6	27.0
		Halogen	31.500	0.712	0.356	30.9	32.3
		U LUME	25.825	4.147	2.073	20.9	30.5
	10.0	3M LED	17.375	1.310	0.655	15.7	18.9
		Halogen	30.200	0.693	0.346	29.6	30.8
		U LUME	27.300	0.497	0.248	26.6	27.7

TABLE II

Summary statistics for ratio: bottom surface/top surface hardness

Material	Distance	Curing unit	Mean	Stddev	Stderr	Min	Max
DELTON	0.5	3M LED	0.148	0.086	0.043	0.03125	0.21277
	0.5	Halogen	0.363	0.065	0.032	0.28571	0.44444
	0.5	U LUME	0.260	0.122	0.061	0.14173	0.42742
	2.0	Halogen	0.261	0.182	0.091	0.10938	0.50256
	2.0	U LUME	0.215	0.043	0.022	0.16990	0.27368
	10.0	Halogen	0.111	0.046	0.023	0.07000	0.16000
USXT	0.5	3M LED	0.496	0.078	0.039	0.43158	0.58989
	0.5	Halogen	0.748	0.055	0.027	0.68000	0.80000
	0.5	U LUME	0.636	0.052	0.026	0.58996	0.69796
	2.0	3M LED	0.256	0.054	0.027	0.22477	0.33621
	2.0	Halogen	0.632	0.026	0.013	0.59443	0.65049
	2.0	U LUME	0.690	0.137	0.068	0.55738	0.85167
	10.0	3M LED	0.095	0.043	0.021	0.04459	0.14368
	10.0	Halogen	0.479	0.019	0.009	0.45455	0.50000

TABLE III

Summary statistics for bottom surface hardness

Material	Distance	Curing unit	Mean	Stddev	Stderr	Min	Max
DELTON	0.5	3M LED	1.200	0.707	0.354	0.3	2.0
	0.5	Halogen	6.050	0.957	0.479	5.0	7.2
	0.5	U LUME	3.275	1.473	0.736	1.8	5.3
	2.0	Halogen	4.800	3.586	1.793	2.1	9.8
	2.0	U LUME	4.200	0.804	0.402	3.5	5.2
	10.0	Halogen	2.050	0.790	0.395	1.4	3.0
USXT	0.5	3M LED	9.050	1.550	0.775	7.3	10.5
	0.5	Halogen	19.100	1.587	0.794	17.0	20.6
	0.5	U LUME	15.375	1.305	0.652	14.1	17.1
	2.0	3M LED	5.200	1.039	0.520	3.9	6.3
	2.0	Halogen	19.900	0.510	0.255	19.2	20.4
	2.0	U LUME	17.400	0.804	0.402	16.5	18.3
	10.0	3M LED	1.675	0.768	0.384	0.7	2.5
	10.0	Halogen	14.450	0.645	0.323	14.0	15.4
	10.0	U LUME	9.875	1.215	0.607	8.7	11.2

TABLE IV

Analysis of the effects of curing source on top surface hardness

Material	Distance	Curing unit	Material	Distance	Curing unit	Lsmean	Stderr	P_value
DELTON	0.5	3M LED	DELTON	0.5	Halogen	-8.500	1.655	0.00004
DELTON	0.5	3M LED	DELTON	0.5	U LUME	-4.250	1.655	0.11149
USXT	0.5	3M LED	USXT	0.5	Halogen	-7.300	1.655	0.00045
USXT	0.5	3M LED	USXT	0.5	U LUME	-5.950	1.655	0.00632
DELTON	0.5	Halogen	DELTON	0.5	U LUME	4.250	1.655	0.11149
USXT	0.5	Halogen	USXT	0.5	U LUME	1.350	1.655	0.99238
DELTON	2	3M LED	DELTON	2	Halogen	-1.900	1.655	0.93025
DELTON	2	3M LED	DELTON	2	U LUME	-3.300	1.655	0.37727
USXT	2	3M LED	USXT	2	Halogen	-10.150	1.655	0.00000
USXT	2	3M LED	USXT	2	U LUME	-4.475	1.655	0.07947
DELTON	2	Halogen	DELTON	2	U LUME	-1.400	1.655	0.99014
USXT	2	Halogen	USXT	2	U LUME	5.675	1.655	0.01048
DELTON	10	3M LED	DELTON	10	Halogen	-8.800	1.655	0.00002
DELTON	10	3M LED	DELTON	10	U LUME	-6.075	1.655	0.00500
USXT	10	3M LED	USXT	10	Halogen	-12.825	1.655	0.00000
USXT	10	3M LED	USXT	10	U LUME	-9.925	1.655	0.00000
DELTON	10	Halogen	DELTON	10	U LUME	2.725	1.655	0.63351
USXT	10	Halogen	USXT	10	U LUME	2.900	1.655	0.55251

[a] p-value with Sidak adjustment.

TABLE V

Analysis of the effects of distance on top surface hardness

Material	Distance	Curing unit	Material	Distance	Curing unit	Lsmean	Stderr	P_value
DELTON	0.5	3M LED	DELTON	2	3M LED	-7.900	1.655	0.00013
DELTON	0.5	3M LED	DELTON	10	3M LED	-1.525	1.655	0.98224
USXT	0.5	3M LED	USXT	2	3M LED	-3.125	1.655	0.45085
USXT	0.5	3M LED	USXT	10	3M LED	0.850	1.655	0.99979
DELTON	0.5	Halogen	DELTON	2	Halogen	-1.300	1.655	0.99420
DELTON	0.5	Halogen	DELTON	10	Halogen	-1.825	1.655	0.94476
USXT	0.5	Halogen	USXT	2	Halogen	-5.975	1.655	0.00603
USXT	0.5	Halogen	USXT	10	Halogen	-4.675	1.655	0.05809
DELTON	0.5	U LUME	DELTON	2	U LUME	-6.950	1.655	0.00091
DELTON	0.5	U LUME	DELTON	10	U LUME	-3.350	1.655	0.35745
USXT	0.5	U LUME	USXT	2	U LUME	-1.650	1.655	0.97025
USXT	0.5	U LUME	USXT	10	U LUME	-3.125	1.655	0.45085
DELTON	2	3M LED	DELTON	10	3M LED	6.375	1.655	0.00282
USXT	2	3M LED	USXT	10	3M LED	3.975	1.655	0.16479
DELTON	2	Halogen	DELTON	10	Halogen	-0.525	1.655	1.00000
USXT	2	Halogen	USXT	10	Halogen	1.300	1.655	0.99420
DELTON	2	U LUME	DELTON	10	U LUME	3.600	1.655	0.26785
USXT	2	U LUME	USXT	10	U LUME	-1.475	1.655	0.98583

[a] p-value with Sidak adjustment.

TABLE VI

Analysis of the effects of curing source on bottom surface hardness

Material	Distance	Curing unit	Material	Distance	Curing unit	Lsmean	Stderr	P_value
DELTON	0.5	3M LED	DELTON	0.5	Halogen	-4.850	0.98	0.00010
DELTON	0.5	3M LED	DELTON	0.5	U LUME	-2.075	0.98	0.30606
USXT	0.5	3M LED	USXT	0.5	Halogen	-10.050	0.98	0.00000
USXT	0.5	3M LED	USXT	0.5	U LUME	-6.325	0.98	0.00000
DELTON	0.5	Halogen	DELTON	0.5	U LUME	2.775	0.98	0.06041
USXT	0.5	Halogen	USXT	0.5	U LUME	3.725	0.98	0.00387
USXT	2	3M LED	USXT	2	Halogen	-14.700	0.98	0.00000
USXT	2	3M LED	USXT	2	U LUME	-12.200	0.98	0.00000
DELTON	2	Halogen	DELTON	2	U LUME	0.600	0.98	0.99914
USXT	2	Halogen	USXT	2	U LUME	2.500	0.98	0.12084
USXT	10	3M LED	USXT	10	Halogen	-12.775	0.98	0.00000
USXT	10	3M LED	USXT	10	U LUME	-8.200	0.98	0.00000
USXT	10	Halogen	USXT	10	U LUME	4.575	0.98	0.00025

[a] p-value with Sidak adjustment.

TABLE VII

Analysis of the effects of distance on bottom surface hardness

Material	Distance	Curing unit	Material	Distance	Curing unit	Lsmean	Stderr	P_value
USXT	0.5	3M LED	USXT	2	3M LED	3.850	0.98	0.00262
USXT	0.5	3M LED	USXT	10	3M LED	7.375	0.98	0.00000
DELTON	0.5	Halogen	DELTON	2	Halogen	1.250	0.98	0.87830
DELTON	0.5	Halogen	DELTON	10	Halogen	4.000	0.98	0.00163
USXT	0.5	Halogen	USXT	2	Halogen	-0.800	0.98	0.99241
USXT	0.5	Halogen	USXT	10	Halogen	4.650	0.98	0.00019
DELTON	0.5	U LUME	DELTON	2	U LUME	-0.925	0.98	0.97936
USXT	0.5	U LUME	USXT	2	U LUME	-2.025	0.98	0.33661
USXT	0.5	U LUME	USXT	10	U LUME	5.500	0.98	0.00001
USXT	2	3M LED	USXT	10	3M LED	3.525	0.98	0.00714
DELTON	2	Halogen	DELTON	10	Halogen	2.750	0.98	0.06450
USXT	2	Halogen	USXT	10	Halogen	5.450	0.98	0.00001
USXT	2	U LUME	USXT	10	U LUME	7.525	0.98	0.00000

[a] p-value with Sidak adjustment.

TABLE VIII

Summary statistics for toothbrush abrasion

Ultraseal Toothbrush Abrasion

Curing Unit	0.5mm (sd)	2mm (sd)	10mm (sd)
Halogen	1.27 (0.30)	1.07 (0.43)	1.36 (0.38)
Ultralume	0.97 (0.18)	1.07 (0.43)	1.33 (0.28)
Freelight	1.54 (0.26) *	1.78 (0.53) *	Not run

Delton Toothbrush Abrasion

Curing Light	0.5mm (sd)	2mm (sd)
Halogen	0.76 (0.33)	0.35 (0.68)
Ultralume	1.13 (0.24)	2.18 (1.15) *

*** = Statistically significant in columns @ p value <0.05**

DISCUSSION

From the results, it seems that there is no one "best" curing method, at least not with the lights and materials that were used in this study. The lights and materials used were chosen as representative of some of the most commonly used materials on the market today, but they are by no means intended or considered to be inclusive of every available technology.

Analysis of the results showed that there were a number of inconsistencies that the practitioner should be aware of, as different combinations yielded different results. For example, the top surfaces were cured best at 2 mm to 10 mm, while the bottom surfaces cured best when the light was 0.5 mm to 2 mm from the material. Also, the entire specimen (bottom to top ratio) polymerized best when the light was at 0.5 mm. Why did the top surfaces record harder values when the light source *was not* at contact with the material? While at the same time, the bottom surfaces were consistently harder when the light *was* closer to the material? These differences in hardness values were not the expected results of this study but are not entirely unfounded or without precedence.

Murchison and Moore[2] conducted a study in which different cavity liners were polymerized by a halogen light at different distances for different exposure times. The specimens were then tested for Knoop hardness values to determine the optimal time and distance for curing. They chose distances of 0 mm, 3 mm, and 6 mm and times of 20 seconds, 40 seconds, and 60 seconds. They found that the greatest hardness values were obtained when the material was cured from a distance of 3 mm in all but one material. The 6 mm distance was better than the 0 mm, or contact, distance in six of the eight materials. The time of 60 seconds provided the hardest cure, but 40 seconds was not significantly different. The time of 20 seconds resulted in significantly different hardness values in seven of the eight materials. The best results were obtained with longer exposure times. Murchison and Moore state that, "It is evident that the hardness values from 3 mm to 6 mm exceed those obtained with the curing source as close as possible to the specimen. The reason for the increase in microhardness from 0 mm to 3 mm curing distance is unknown."[2] Murchison and Moore go on to state that this is actually a good thing, due to the inherent nature of the placement of cavity liners, as they are often difficult to access, the preparations can be limiting, and the maneuvering of the light source can be challenging. Therefore, contact (or 0 mm) would not be the ideal distance anyway. They conclude that further research needs to be conducted to explain the differences found in the Knoop hardness values between the specimens cured at the further distances. These results are relevant to the current study in that the hardness values do not follow the predicted course or supposed outcome. We have found that the hardness values vary depending upon the light, the material, and the surface (being top or bottom). Murchison and Moore only looked at the top surface and, therefore, no conclusions can be drawn about the bottom or depth of cure. However, other studies have found similar results when testing both bottom and top surfaces of prepared specimens.

One of those studies, by Kim et al.[52] found that different light sources produced different results when used to cure various sealant materials. That study used five sealant materials and polymerized different samples with a conventional halogen light and a plasma-arc curing (PAC) light for different lengths of time. They then tested the top and bottom surfaces of the samples for microhardness and wear and found that top surfaces of the specimens cured with the halogen light had a higher microhardness value than the bottom surfaces. Yet, in the samples that were polymerized with the PAC light, three of the sealants had higher values on the bottom surfaces than on the top. One of these materials, Ultraseal XT plus, had a harder surface on the bottom for all curing times of greater than 6 seconds. Kim et al. suggest that this result may be due to the light intensity, penetrability, or reflection, but they indicate that the exact reason is unknown and requires further research. The wear resistance of the samples was also tested, and it was found that the samples polymerized with the PAC light exhibited less wear than those from the halogen light. The authors conjecture that this may be due to the thorough polymerization of the material by the higher intensity light source. But, if the higher intensity source provides a more thorough polymerization, why is the top surface softer than the bottom? Some sources say that bottom surface polymerization is dependent upon exposure duration,[67] while others claim that light intensity is more important.[77] Still others say that both factors are important for complete polymerization, especially of bottom surfaces, but are limited to a maximum of depths less than 2 mm.[36,78]

Park et al.[64] also completed a study using different lights to cure composite resin materials. They also used a conventional halogen light and a PAC light to polymerize samples for different amounts of time. The samples were then tested for hardness using the Vickers hardness test. With one of the materials in the study, the bottom surfaces were harder than the top surfaces when polymerized with the halogen light. The differences were not found to be statistically significant, but there were differences nonetheless. The samples were cured from "as close as possible" to the material as they could get the light. Park et al. found that the longer the duration, the harder the bottom surface and, when using the PAC light at shorter times, the bottom surface did not polymerize completely. The halogen light gave a more even polymerization when using the manufacturer's recommended times, but the PAC light needed longer than recommended times to get the same results. Note that complete cure was achieved with the PAC light at significantly shorter times than the halogen, but at longer than the manufacturer's recommended times. Again, why the difference in top and bottom polymerization and why was the bottom harder in some samples with the halogen light? According to Rueggeberg and Craig,[1] as the top surface of the composite begins to cure, the light transmission decreases significantly and has a more difficult time getting through to the deeper layers, therefore, the hardness values decrease. Rueggeberg and Craig hypothesize that the rapid polymerization by the PAC light created a top layer that became too thick, too rapidly, to allow deep penetration of the light, even though the light was a higher energy density. The halogen samples had higher values on the bottom because the top surfaces did not polymerize so rapidly as to block the light from reaching the lower levels. "Slow and steady" seems to be the effective mantra here. The authors concede that this hypothesis needs further research, but it does seem to have merit.

Hansen and Asmussen[35] found in their research that depth of cure diminished in a linear fashion with increased distance from the light source. Yet, they indicate that the relationship is dependent upon several factors, with the main factor being the degree of divergence of the light. The authors go on to say that as the light penetrates the upper levels of the material, the absorption in the material prevents the light from reaching the deeper parts. This must then be overcome by increased time when a higher intensity light is used, or decreasing the thickness of the material when a conventional, or weaker, light is used.[36]

The findings of the Hansen and Asmussen[35] and Park et al.[64] research relate to the present study in that the differences in top and bottom hardness seem to be related to light intensity and the level of intensity at deeper levels of material. Again, further research needs to be conducted in this area, and a pursuit of the answer as to why these results were found is beyond the scope of this thesis. Suffice to say that it seems that light intensity is the key to deeper and more complete polymerization, but it can be affected by a large number of variables. It may be compensated for by altering the distance, changing the material, using a different light source, or increasing the duration of the exposure. The unanswered question seems to be what combination creates the ideal situation in the most clinical situations.

CURRENT LITERATURE

The data in this study were collected over a period of two years from 2001-2003. Similar studies done more recently have shown similar data and have prompted similar conclusions. Even when using next-generation curing lights and different resin materials, researchers obtained many of the same results.

One study tested four different LED lights from six different distances and found that light intensity and depth of cure decreased overall with greater distance. However, there was enough variation between lights that the researcher determined that "while both intensity and depth of cure decrease with increasing distance, the relationship between these factors and distance may not be similar for all lights and may depend on the characteristics of individual lights."[82]

Another study looked at polymerization of resin samples from three different distances with the same results. Light tip distance was shown to be an important factor in obtaining an adequate cure of the material.[83] Other researchers conducted a study similar to this project. Three lights were used at three different distances but were used to test bond strength of a glass ionomer bonding agent instead of surface hardness of a resin material. Nevertheless, the results showed that bond strength decreased with greater distance with all lights, but the LED light samples failed first, followed by the halogen light and finally the PAC light. Even with the different material, the results lead to the conclusion that distance and light source play an important role in polymerization and curing ability.[84]

A final study that was reviewed tested different light tip distances for different time periods for shear bond strength of a single bonding agent material. As expected, the researcher found that the strength of the bond decreased with increased distance, however, the bond increased with increased time. This lead the researchers to conclude that increasing the curing time could compensate for poor polymerization due to increased distance.[85]

Timing may be the key to achieving proper polymerization of light cured materials, yet each material recommends different curing times and each light manufacturer gives different claims as to their products' abilities. There could conceivably be an endless amount of variations that each practitioner could come up with when using different lights and material. What may work for one of these variables may not be ideal for another. The data here and in the current literature suggest that the practitioner be familiar and confident with whatever products they choose.

CLINICAL SIGNIFICANCE

As indicated in the introduction, a 2mm thickness of sealant is a realistic clinical situation. Hence the clinician needs to know whether such a thickness of the sealant used is adequately polymerized by the technique employed. The definition of adequately polymerized is somewhat open to discussion. Both ADA and ISO specifications for sealants simply removed uncured material with a plastic instrument and define the remainder as the depth cured. The ratio of bottom to top hardness has also been frequently employed in the literature and was chosen for use here. Most reports use either 0.8 of 0.75 as a minimum value. With either value, only the halogen light at contact results in an adequate cure for Ultraseal and Delton does not meet the criteria for any light or distance combination. The reader should be cautioned that the materials employed represent those in use in 2003. Curing lights in particular have experienced significant changes since then and LED lights are available with output considerably higher than the quartz light used in this study. The clinical implications of placing a sealant of 2mm or greater depth with an uncured bottom surface are uncertain but leakage, loss of retention and potential biological effects from unreacted components of the sealant are all possibilities.

SUMMARY AND CONCLUSIONS

SUMMARY

In general the halogen light source outperformed the two LED lights in this study and the Ultraseal XT outperformed the Delton sealant material. It is important to remember that both dental materials and devices such as curing lights are continually under development and that the results here represent materials and devices in common use in 2003.

These data should be taken into consideration when using sealant material as a flowable composite, in a deeper restoration, sealing a “deep” or opened pit/fissure, or merely placing a normal “thin” sealant. The optimal distance would depend upon which light is used, which material is chosen for use, and what purpose the material is being used for.

CONCLUSIONS

According to these data, a practitioner may come to the conclusion that generally a normal (thin layer) sealant seems to be cured best at a light-to-resin distance of 2 mm, while a deeper (thicker) restoration would more likely be cured better at a distance of 0.5 mm. Yet, it may be that the optimum level of light intensity is very different for different lights and, therefore, each light may have an ideal time, distance, and material that it is best suited for. Unfortunately, real-world practitioners cannot test each light for each material, time, and distance in order find the best match. Even if that were possible, it would not be practical to use a different light, setting, distance, etc., for each different restoration material that was used. Add to that the constantly changing dynamics of new technology and materials available, and the problem continues to compound.

It is important for the practitioner to be familiar with the materials that they use. Manufacturers' claims do not always hold true for their own products, let alone across product lines. The ultimate responsibility lies with practitioners to be familiar with and knowledgeable about the products they choose in their practices.

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ABSTRACT

BACKGROUND

The efficacy of sealants to aid in the prevention of pit and fissure caries is well documented. In order for the sealants to be effective, they must be placed properly and retained for as long as possible. Clinicians must be aware that the proper placement of sealants is technique-sensitive and must be well controlled in order to achieve the best results. This study aims to determine if certain variables have an effect on curing of the sealant material to a degree that would compromise its integrity, strength, and longevity.

METHODS AND MATERIALS

Two commonly used sealant materials Ultraseal XT (Ultradent Products Inc., South Jordan, UT) and Delton (Dentsply International, Woodbridge, Ontario, Canada) were chosen and tested for microhardness and abrasion resistance after they were polymerized. This study did not focus on the materials themselves, but rather the technique by which they were polymerized and what effect this had on the materials.

Three separate light sources, a traditional halogen light (QHL75, Dentsply International, Woodbridge, Ontario, Canada), and two newer LED lights (Ultralume LED, Ultradent Products Inc., South Jordan, UT; and 3M Freelight LED, 3M Corp, St Paul, MN) were used in this study. The materials were then cured with each light at each of three different distances: contact (0.5 mm), 2 mm, and 10 mm. The effects of light source variation and distance from the material at the time of polymerization was then evaluated for any significance to sealant placement technique.

Specimens were tested for each variable combination of sealant material, light source, and distance between the two while curing. Six samples were tested for each variable grouping for abrasion resistance, and four separate samples were tested from the same grouping for Knoop hardness. The results were analyzed for significance to determine if certain techniques are or could be beneficial or damaging to the quality of care provided by today's practitioners.

RESULTS

It was found that materials and light sources varied in combination and with different techniques (e.g., distance). In general, the top surface polymerized best when cured at a distance of 2 mm to 10 mm, while the bottom surface polymerized best at a distance of 0.5 mm. The halogen light consistently outperformed the two LED lights, with the 3M LED consistently producing the worst results.

CONCLUSIONS

The halogen curing light used in this study outperformed the LED lights in almost every category, despite the LED light manufacturer's claims of equality. For more reliable polymerization, the halogen light should be used.

SIGNIFICANCE

The practitioner must be aware of the material that he/she is using and how the chosen light source polymerizes that material. Manufacturers' claims and recommendations cannot be trusted to accurately produce the best results with every product on the market today, sometimes not even with the manufacturers' own products. It is crucial for practitioners to be well versed and knowledgeable about the products that they use, based on current research and not manufacturers' claims.

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